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# CALIBRATION TESTS OF THE MSFC 14 X 14-INCH TRISONIC WIND TUNNEL

by ERWIN SIMON
Aero-Astrodynamics Laboratory



NASA

*George C. Marshall Space Flight Center, Huntsville, Alabama*

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## ABSTRACT

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This report presents calibration data obtained from the MSFC 14 x 14-inch trisonic wind tunnel for the Mach range of .2 through 5.0. Pressure distribution data for the 20° cone-cylinder are presented for the Mach range of .90 through 5.00. Static pipe Mach number surveys are presented for the entire calibrated Mach range of .2 through 5.0. Flow inclinations are presented for the Mach range of .2 through 5.00.

Author

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FACILITIES BRANCH
AERODYNAMICS DIVISION
AERO-ASTRODYNAMICS LABORATORY
RESEARCH AND DEVELOPMENT OPERATIONS

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## SUMMARY

This report presents calibration data obtained from the MSFC 14 x 14-inch trisonic wind tunnel for the Mach range of .2 through 5.0. Pressure distribution data for the 20° cone-cylinder are presented for Mach range of .90 through 5.00. Static pipe Mach number surveys are presented for the entire calibrated Mach range of .2 through 5.0. Flow inclinations are presented for the Mach range of .2 through 5.00.

## I. INTRODUCTION

This report presents data obtained from a series of calibration tests conducted in the 14 x 14-inch trisonic wind tunnel at the George C. Marshall Space Flight Center, and supersedes prior calibration reports.

This calibration report will not elaborate upon the facility but will serve as a supplement to the General Tunnel Handbook to be published at a later date. The report is intended for use by present and potential users of the tunnel and associated groups.

Mach number distributions are presented for the entire calibration Mach range of 0.20 through 5.00.

Cone cylinder pressure distributions and flow angularities are presented for transonic Mach numbers. Data are presented in plotted form only with the tabulated data on file at the Wind Tunnel Facility.

The report is divided into two general areas: a description of the facility, the equipment, and the test techniques employed during the testing and the plotted data, presented in Appendices A, B, and C.

The MSFC 14-inch tunnel is a single-pass blowdown type with either atmospheric or vacuum exhaust and is capable of operation over the Mach range of .20 through 5.0 by the use of interchangeable test sections. The stagnation pressure range is from 1 to 7 atmospheres with a controlled temperature normally around 100°F. The transonic test section utilizes interchangeable nozzle blocks for Mach numbers to 2.50 and the supersonic section employs a single set of fixed contour movable blocks to obtain Mach numbers of 2.74 through 5.0.

The transonic test section incorporates the unique feature of having a variable porosity test section. This feature enables optimum wall porosities to be set for the critical transonic Mach numbers. Mach numbers are set in the transonic range by varying the plenum suction using the auxiliary vacuum.

The tunnel operating parameters are given in Figure 4.

## II. APPARATUS AND TEST PROCEDURES

Four approaches were taken at the 14-inch tunnel to obtain an accurate tunnel calibration. The calibration of the transonic section involved utilization of a 20° cone-cylinder, a static pipe, and two yaw heads. The supersonic section was calibrated [1], using a traversing probe.

The 20° cone-cylinder utilized 42 pressure taps and was 18 inches in length and 1.5 inches in diameter and was primarily used to establish optimum pressure profiles in the transonic Mach range. Tunnel blockage of the model was approximately 1 percent. The static pipe was used in the subsonic and transonic Mach range to establish the resulting Mach number distributions. The static pipe extended through the test section and well up into the nozzle section. Static orifices were located every inch along the tube for 26 inches beginning at tunnel station nine and ending at station 35. The normal test rhombus is between station 12 and 26.

The supersonic section was previously surveyed by a total pressure traversing probe which utilized a 50 psia Statham transducer. Total pressure readings were obtained continuously from station 12 through 32 and plotted directly by an automatic plotter.

Once satisfactory Mach number and pressure distributions has been established, a flow inclination check was made at tunnel stations 13, 21, and 27 utilizing a spherical and a conical yaw head. Each yaw head had a diagonally opposed set of orifices in the pitch plane of the tunnel to which a ±5 psid pressure transducer was connected. The yaw head was pitched to ±2 degrees in half degree increments and then rolled 180 degrees and the procedure repeated.

With exception of the yaw heads and the traversing probe, all pressures were simultaneously scanned by a bank of 8 scanivavles, each utilizing a 12 1/2-psi differential pressure transducer.

The calibration probes are illustrated in Figure 3. Test section and installation sketches are Figures 1 and 2.

Pressure data were read out on an eight channel data system and punched into IBM cards where they were then reduced by the tunnel computer to the desired parameters.

## III. RESULTS AND DISCUSSION

In the calibration of the 14 x 14-inch tunnel, special emphasis was placed on the recently installed variable porosity transonic test section. The problem of shock cancellation in the transonic Mach range is a serious problem in the smaller tunnels where wave reflections can interfere with the model being tested. Various studies [2] have shown that optimum wave cancellation occurs at different wall porosities. Since wall porosity could not be varied with the earlier fixed porosity walls, a new set of variable porosity walls were designed and installed. The result was a marked improvement in flow qualities.

It was established early during the initial cone-cylinder calibrations that wave cancellation was influenced not only by wall porosity but also to a lesser extent by tunnel parameters such as wall angle, diffuser opening, and plenum suction. The resulting optimum transonic settings then involved detailed testing where all influencing parameters were varied in different combinations. Once the optimum conditions had been determined, the static pipe was installed and a complete centerline survey was made of the transonic test section from .20 Mach number to 2.50 Mach number. A flow inclination calibration was then made as a conclusion to the transonic calibration.

The cone-cylinder test data in Appendix A were compared to interference free data obtained from AEDC's (PWT-16-T) 16-foot transonic tunnel. As previously mentioned, a marked improvement was made to the pressure distributions from prior calibrations but some slight perturbances still exist in the pressure profiles.

The pressure disturbances on the cone could be attributed to slight surface discontinuities but the cylinder pressures are concluded to be the result of tunnel conditions.

These results are considered to be the optimum conditions presently obtainable and although constant improvements are being sought, any further improvement would presumably necessitate additional concepts to be developed on the design of the variable porosity walls.

The final displacement of the 14-inch tunnel pressure data from the interference free data did not vary more than 6 percent which corresponded to a pressure variation of approximately .15 psia at the most severe case presented.

All of the data presented for the supersonic (Mach 2.75 - 5.00) section were obtained from a prior calibration [1]. The Mach number distribution shows an increasing error in the higher supersonic Mach number region but this is credited to the nozzle design. The supersonic nozzle consists of a set of fixed contour blocks designed for optimum performance at Mach four. The blocks are translated and tilted to achieve the Mach range of 2.75 through 5.00.

The nominal Mach number deviation for the transonic test section is .014 and for the supersonic section is .028. A maximum deviation of .065 occurs at Mach 4.96. These values are based on the normal test rhombus only. The Mach distribution data are presented in Appendix B.

The flow inclination was checked utilizing a spherical and a conical set of yaw heads. Runs were made with the yaw heads at 0 degrees and 180 degrees to eliminate any effects of asymmetry. The intersection of the two roll angles on the pressure versus angle-of-attack plots provided the flow inclination at that point. Surveys were taken at tunnel stations 13, 21 and 27. Flow inclination was normally less than ±.25 degree with the only exceptions occurring at station 13 for Mach numbers 1.2 through 1.3. The plotted data are presented in Section II.

The data for Mach 2.5 are not presented in this report because of the poor flow qualities existing at this Mach number. While the cone-cylinder pressure data appear fairly uniform, the Mach distribution from the static pipe varies from 2.56 to 2.39. This apparently results from uncancelled waves that are readily observed on Schlieren photographs and shadowgraphs taken at this Mach number. Plans are being made to correct this condition and when suitable flow is obtained with this set of blocks, an addendum to this report will be issued.

Measuring accuracy based on overall system performance, assuming additive errors, is estimated to be nominally around one percent.

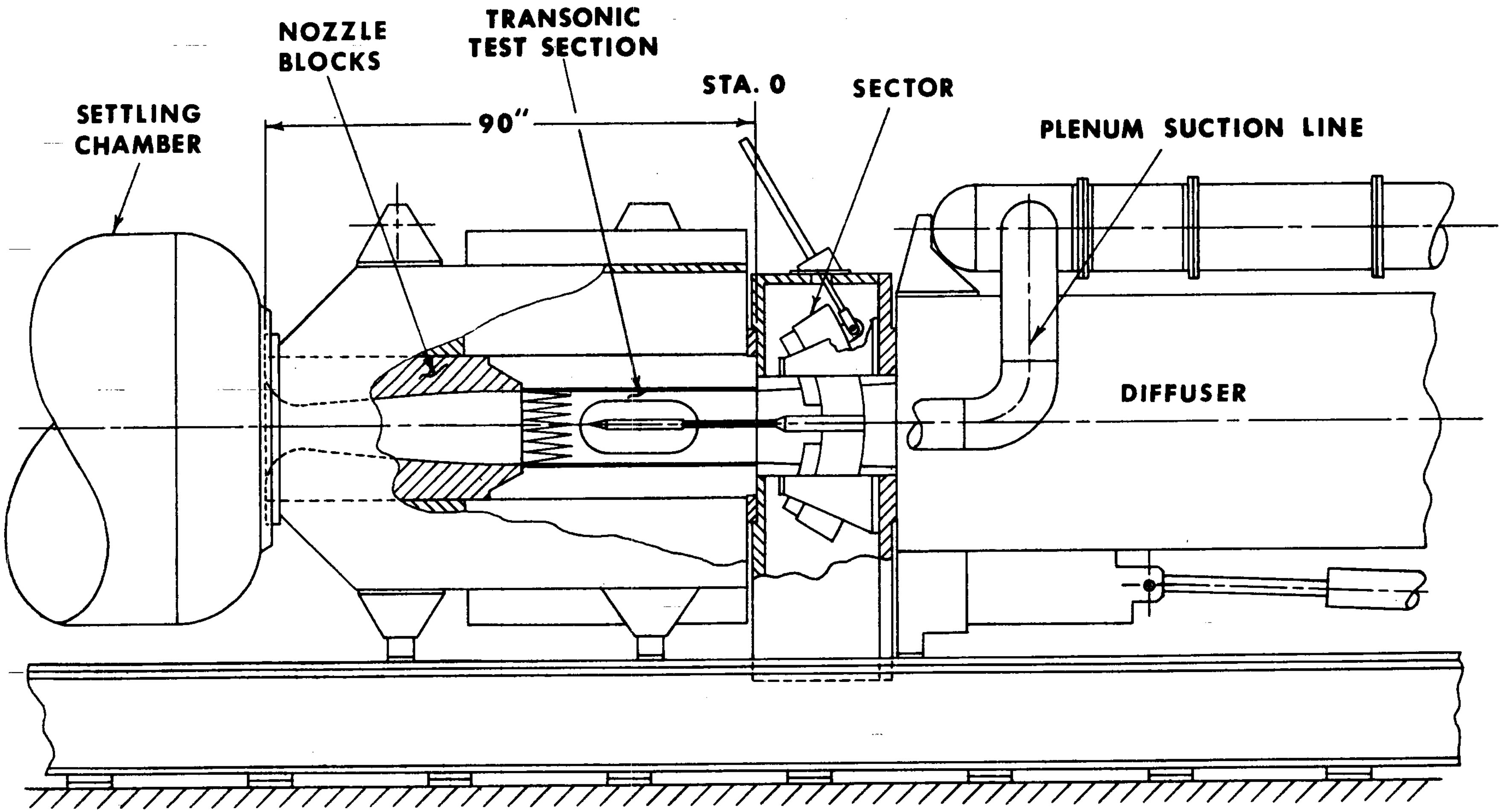
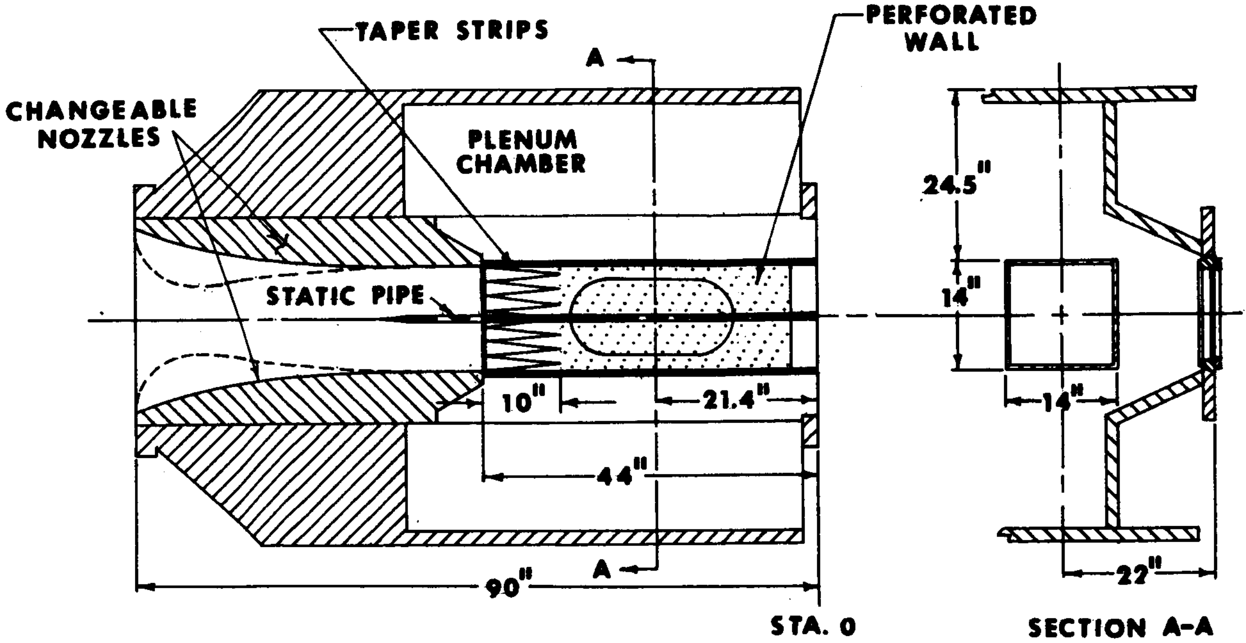
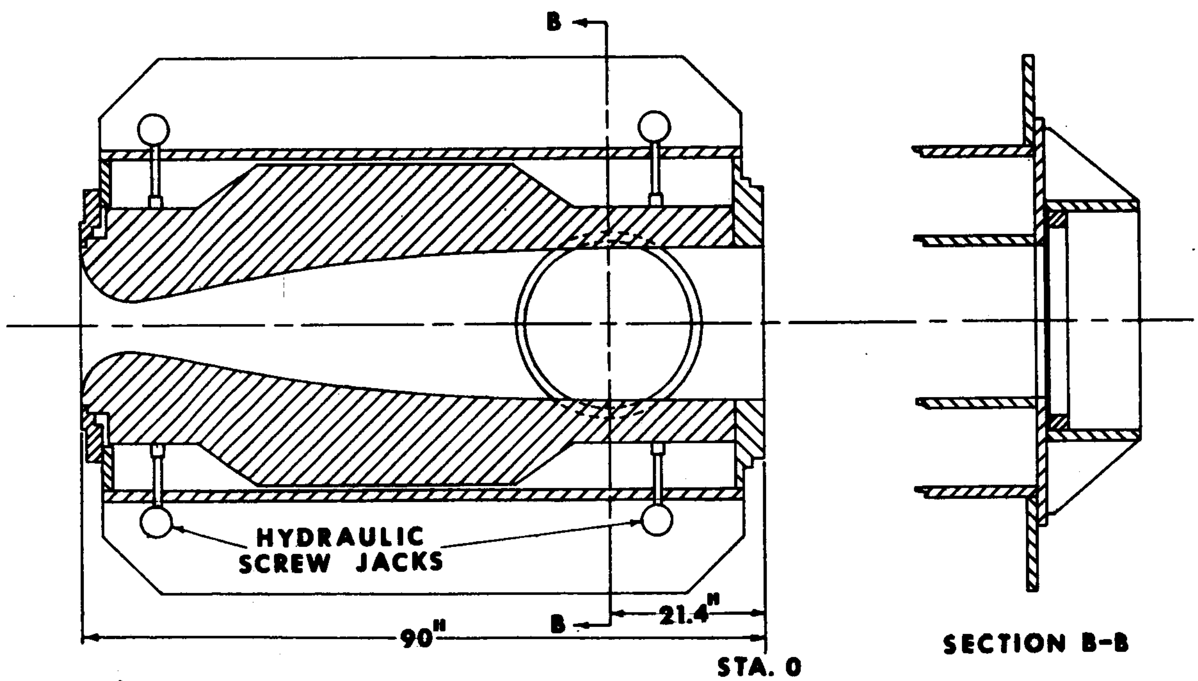



FIGURE 1. 14 X 14-INCH TRISONIC WIND TUNNEL(SCALE 1/30)




SCHEMATIC OF TRANSONIC TEST SECTION




SCHEMATIC OF SUPERSONIC TEST SECTION

FIGURE 2. 14 X 14-INCH TRISONIC WIND TUNNEL TEST SECTIONS

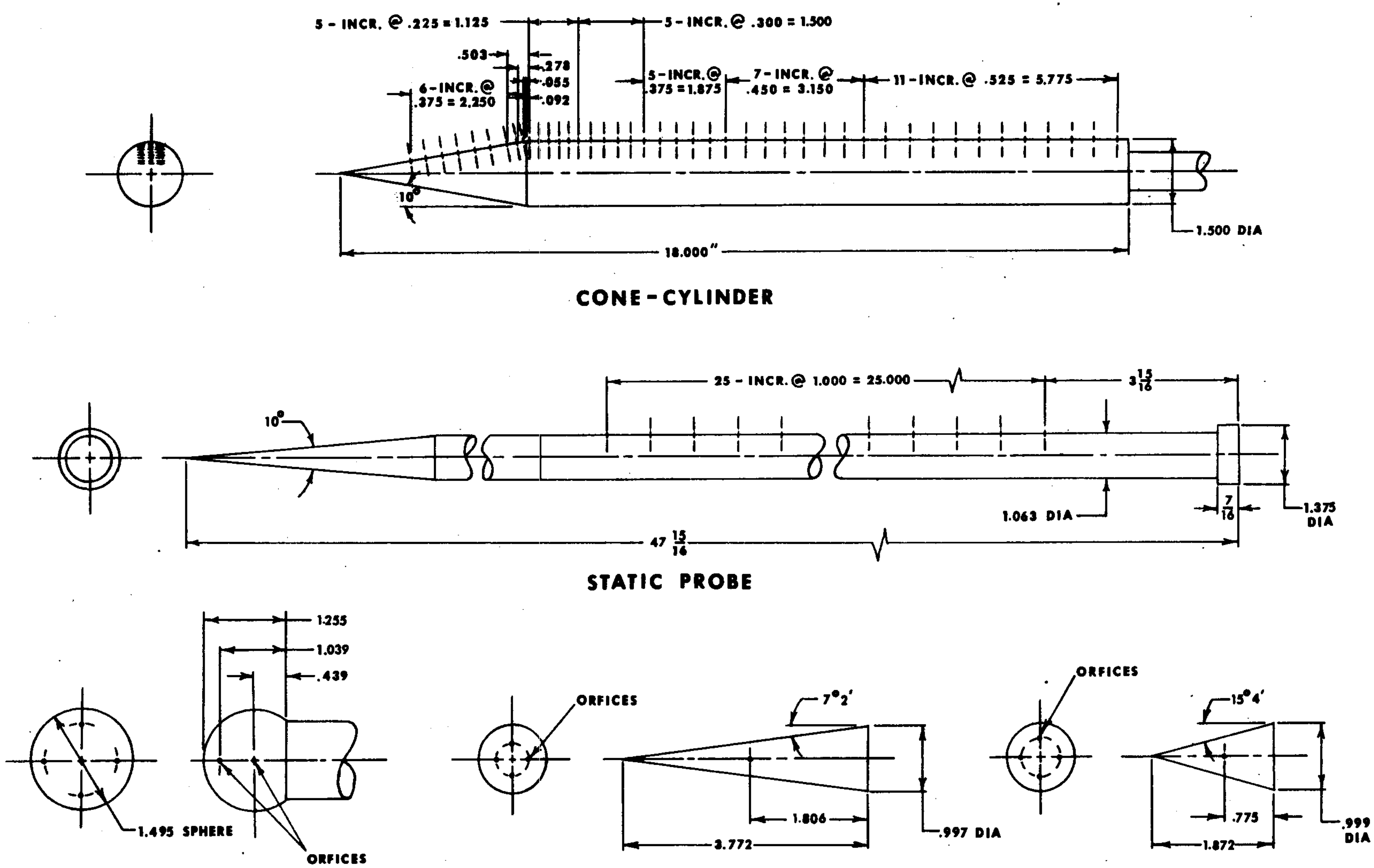
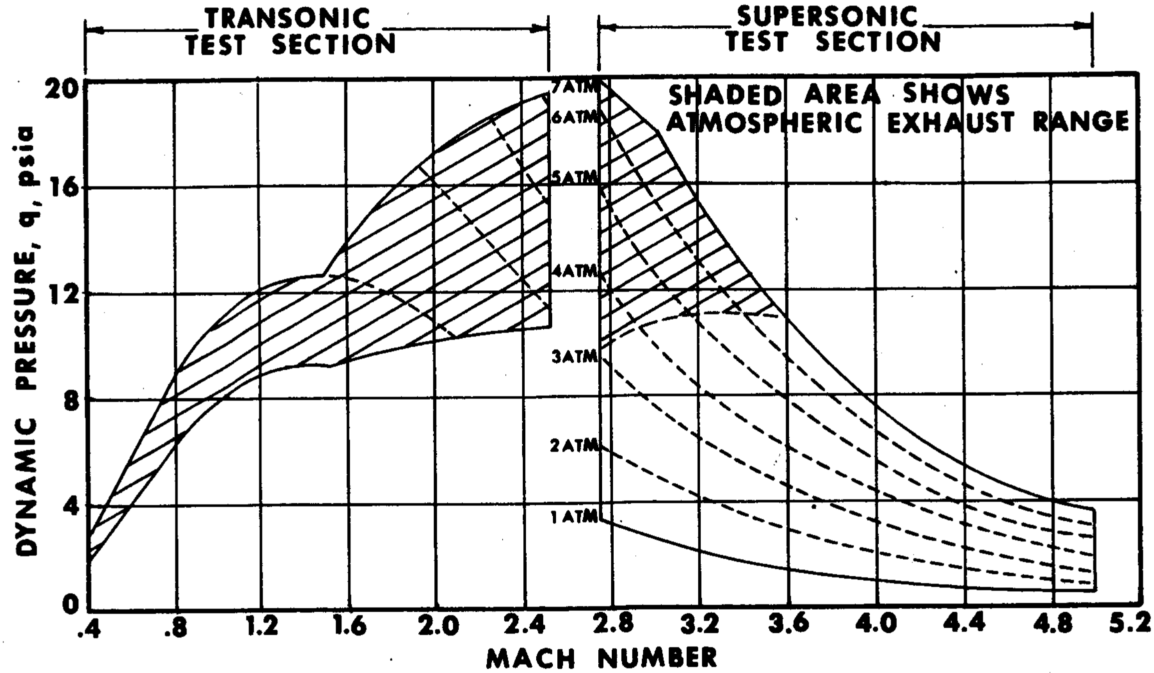



FIGURE 3. YAW HEADS




14 X 14 - INCH TUNNEL DYNAMIC PRESSURE ENVELOPE

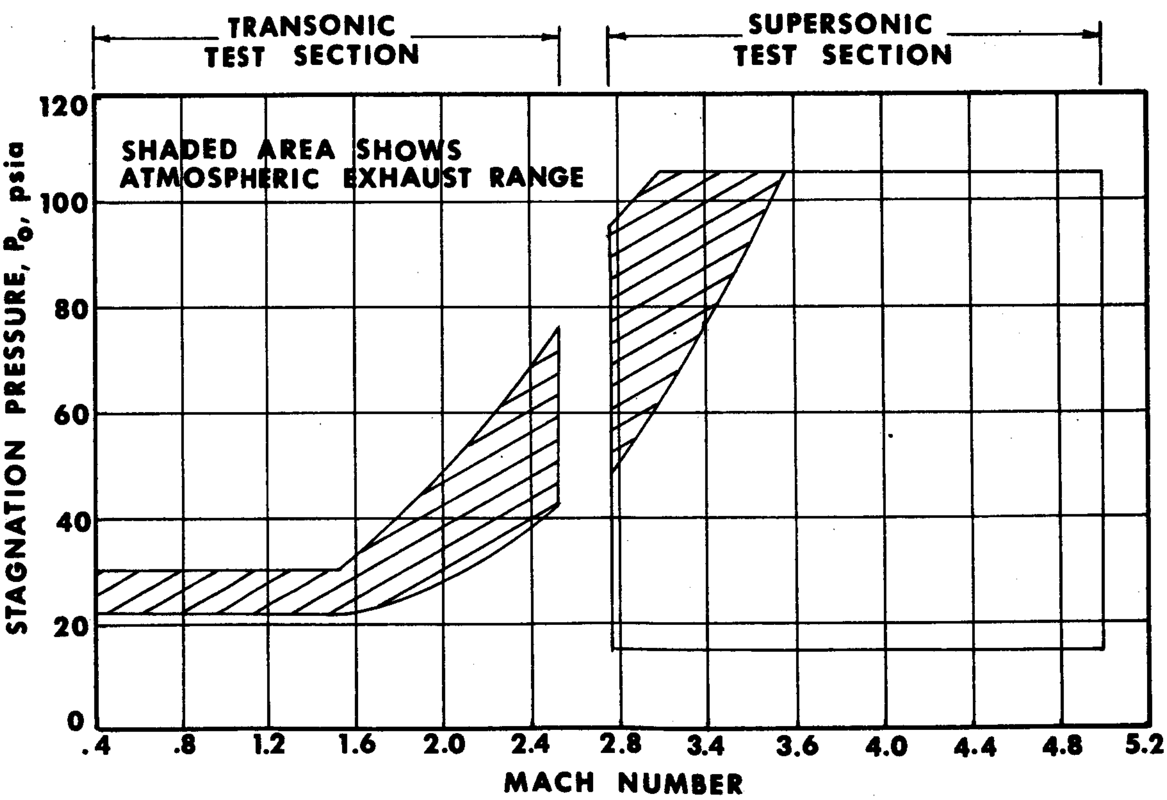
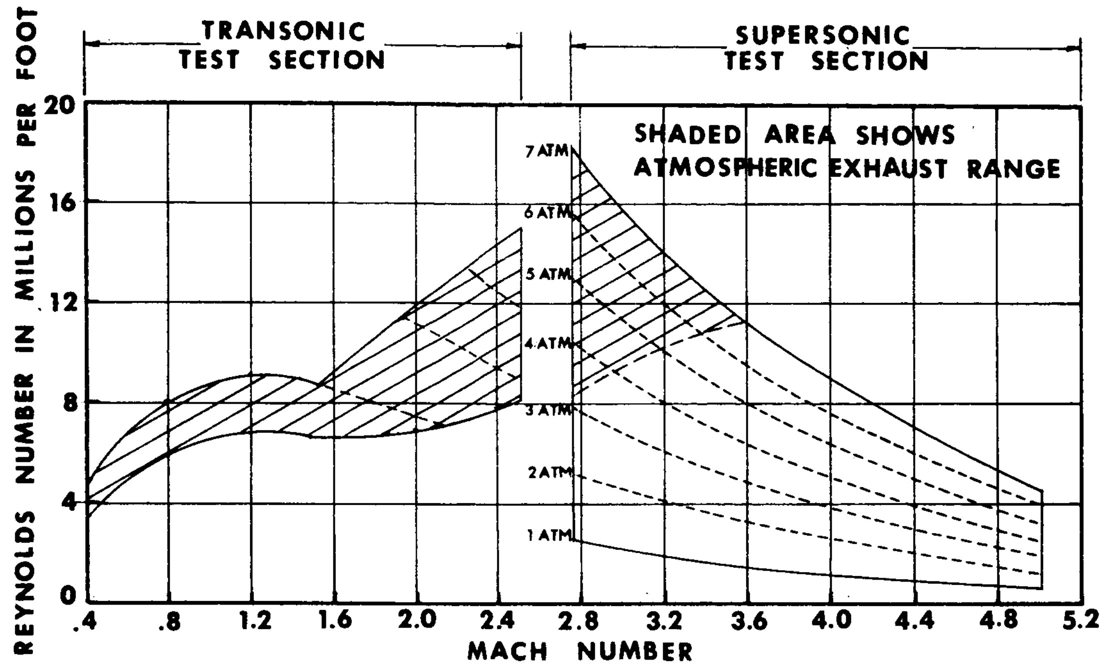



FIGURE 4. 14 X 14-INCH TUNNEL STAGNATION PRESSURE ENVELOPE




14 × 14 - INCH TUNNEL REYNOLDS NUMBER ENVELOPE

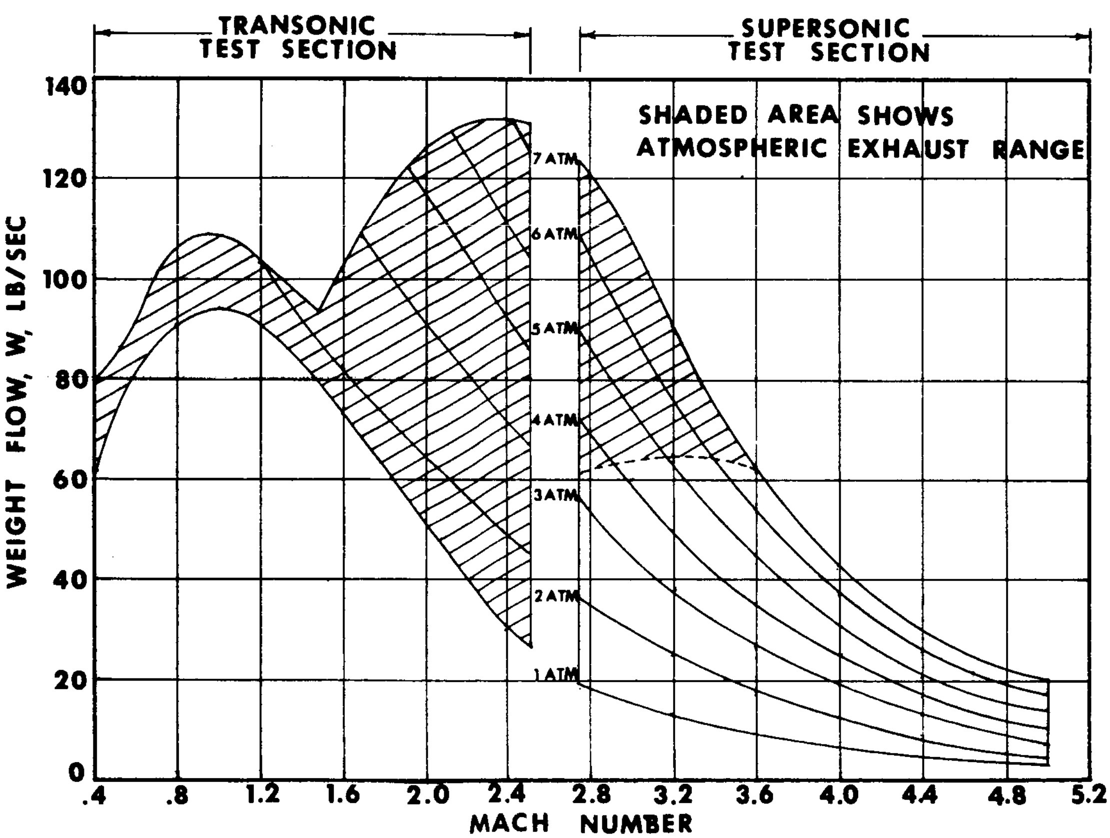



FIGURE 4(Cont'd). 14 X 14-INCH TUNNEL WEIGHT FLOW ENVELOPE

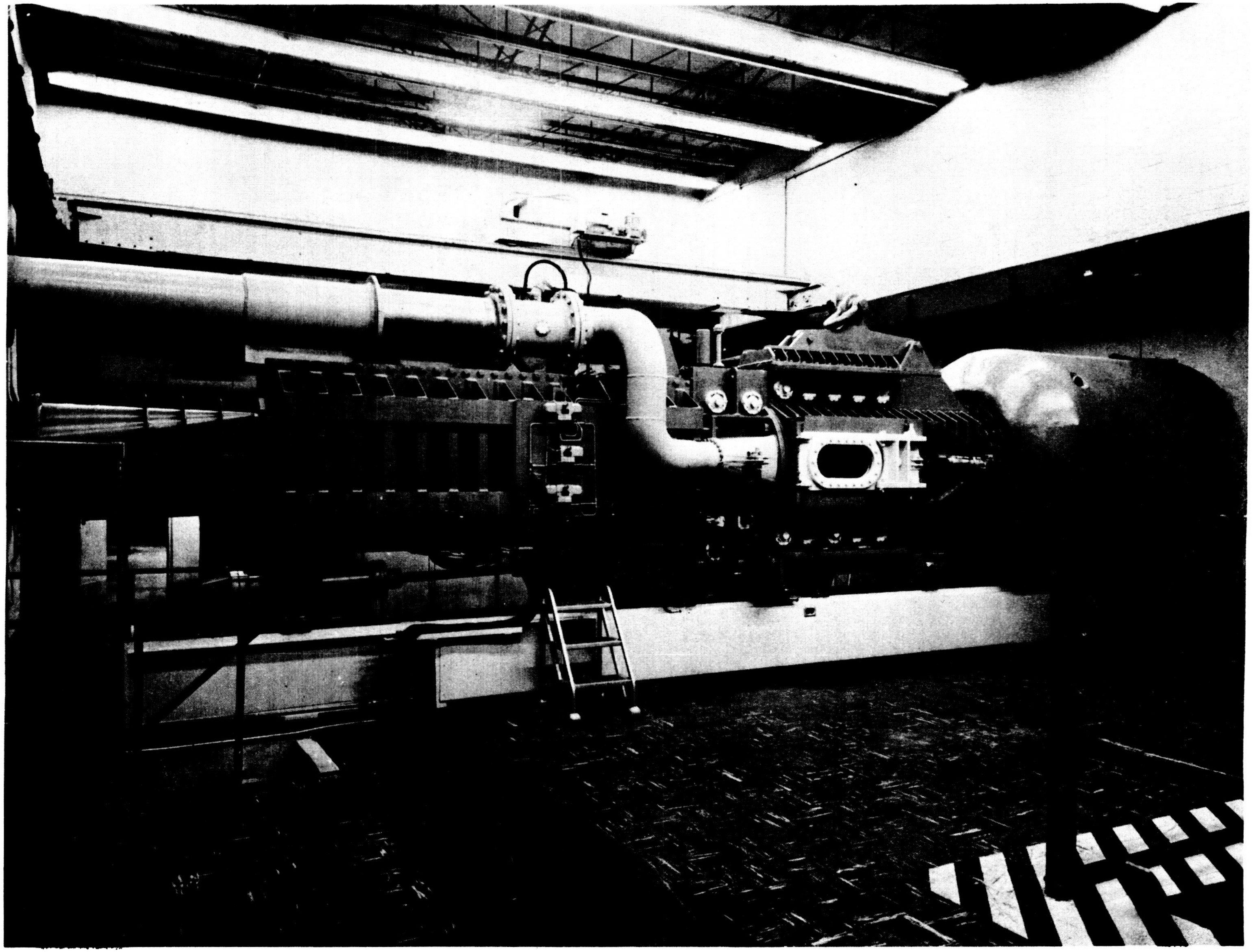
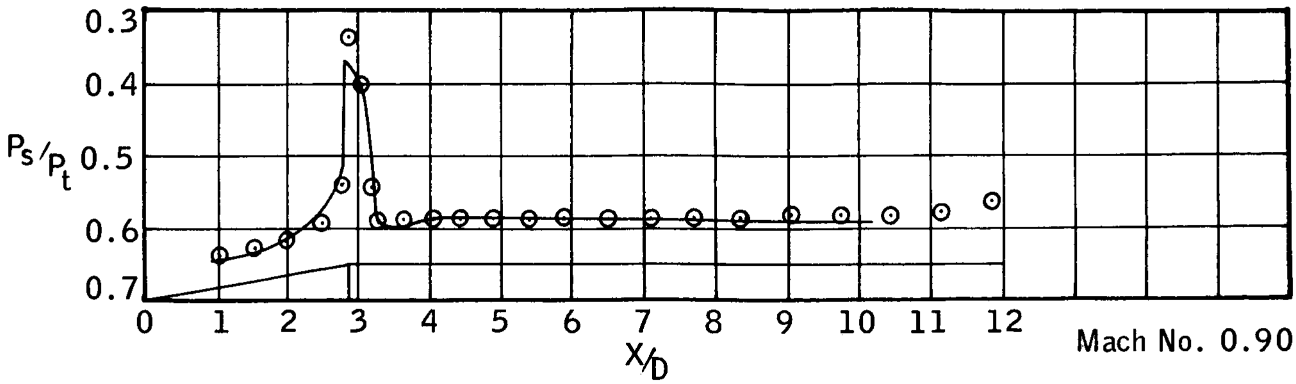
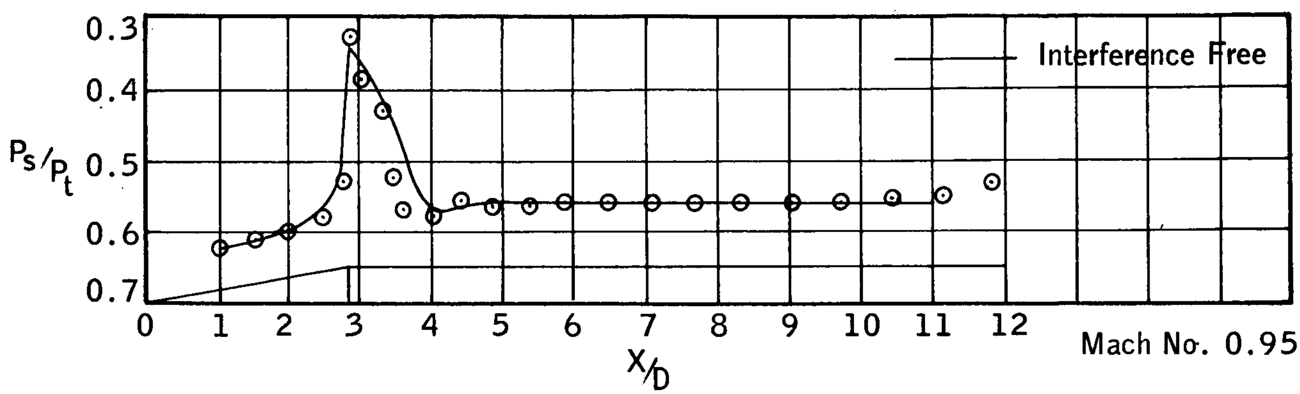


FIGURE 5. 14 X 14 INCH TRISONIC WIND TUNNEL WITH TRANSONIC TEST SECTION INSTALLED

# APPENDIX A

## Transonic Cone-Cylinder Pressure Distributions


0.3
0.4
$P_s/P_t$ 0.5
0.6
0.7
0 1 2 3 4 5 6 7 8 9 10 11 12
X/D
Mach No. 0.90


Interference Free
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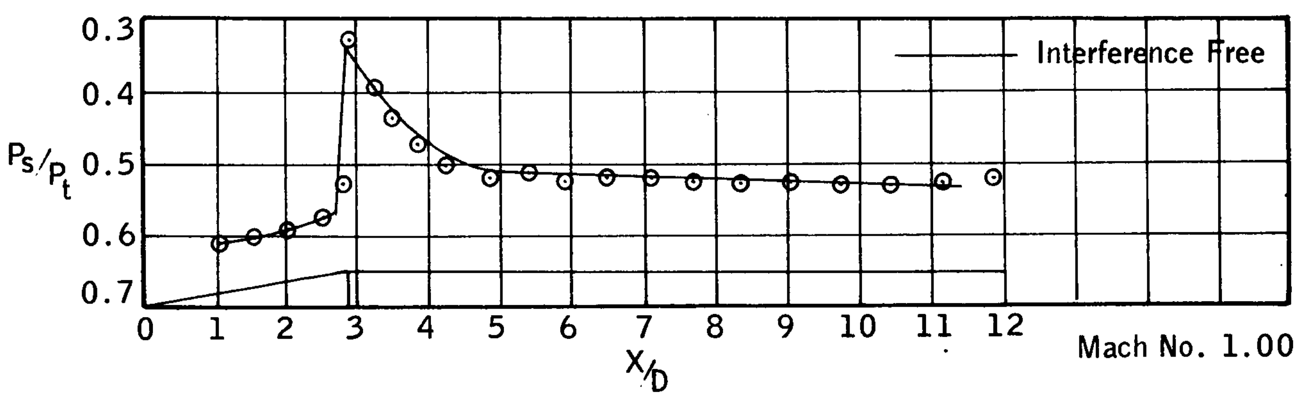
0.6
0.7
0 1 2 3 4 5 6 7 8 9 10 11 12
X/D
Mach No. 0.95


Interference Free
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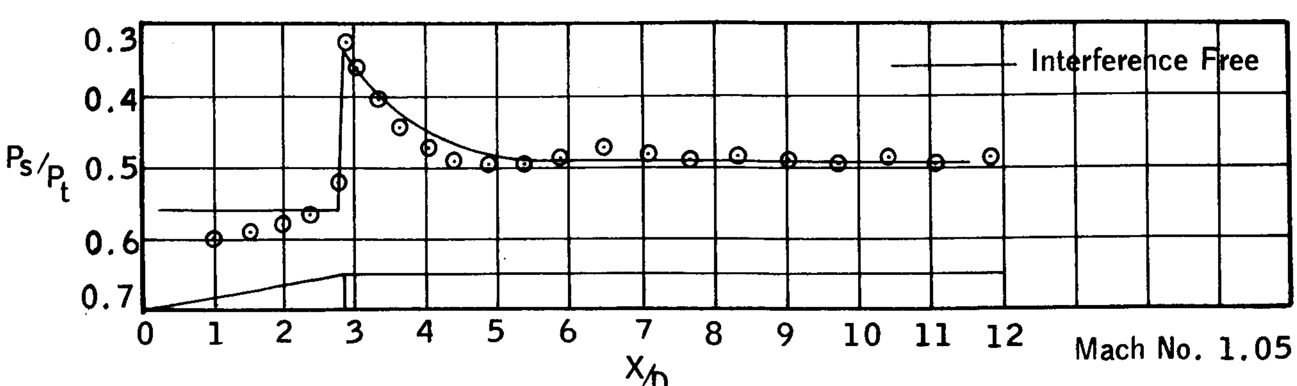
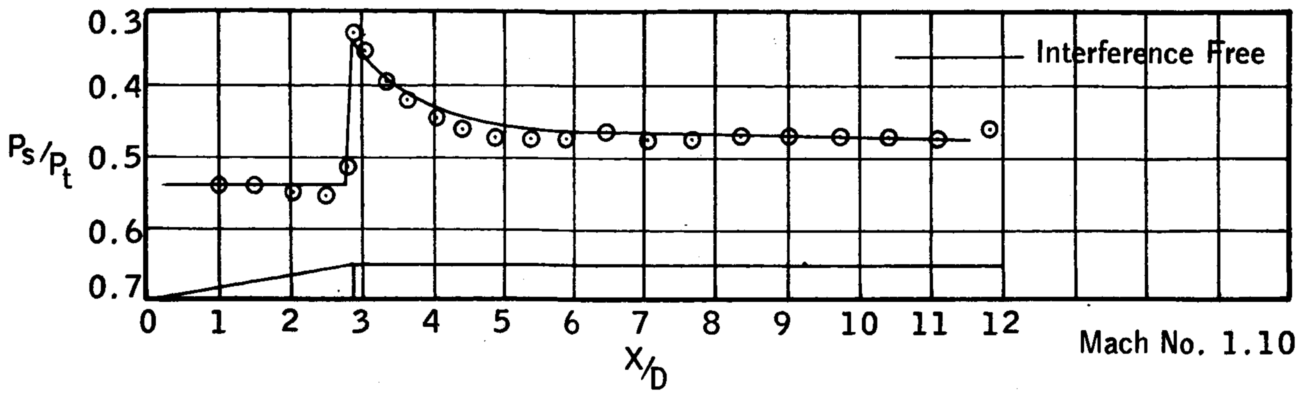
$P_s/P_t$ 0.5
0.6
0.7
0 1 2 3 4 5 6 7 8 9 10 11 12
X/D
Mach No. 1.00


Interference Free
0.3
0.4
$P_s/P_t$ 0.5
0.6
0.7
0 1 2 3 4 5 6 7 8 9 10 11 12
X/D
Mach No. 1.05

Transonic Cone-Cylinder Pressure Distribution

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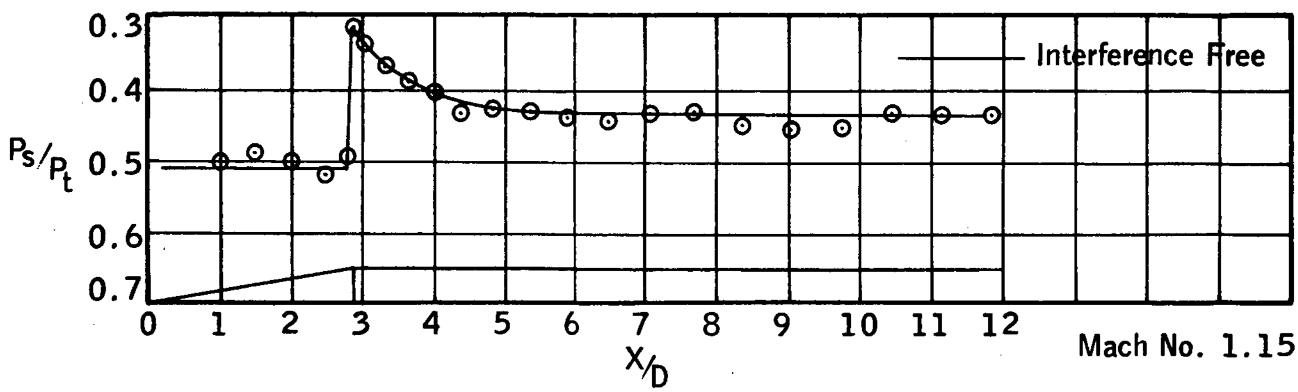


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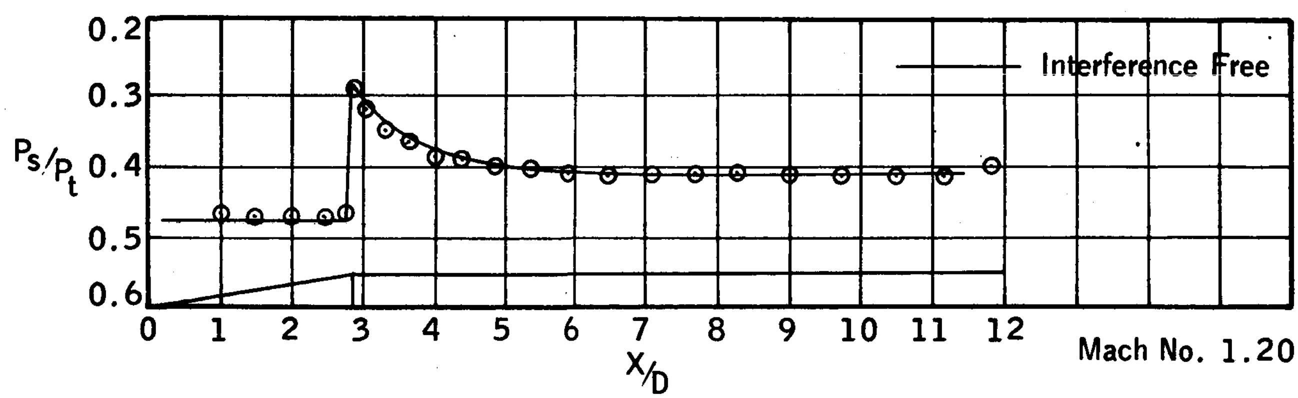


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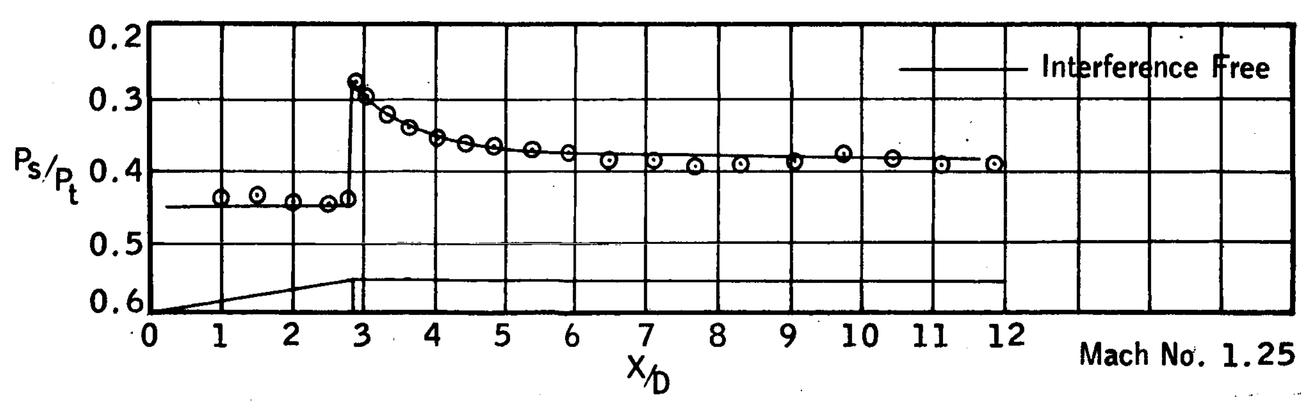
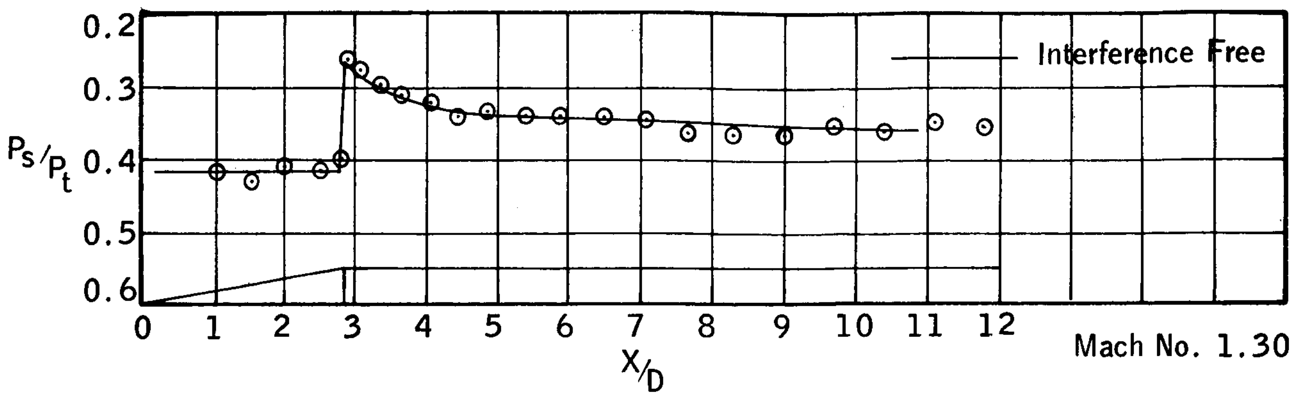
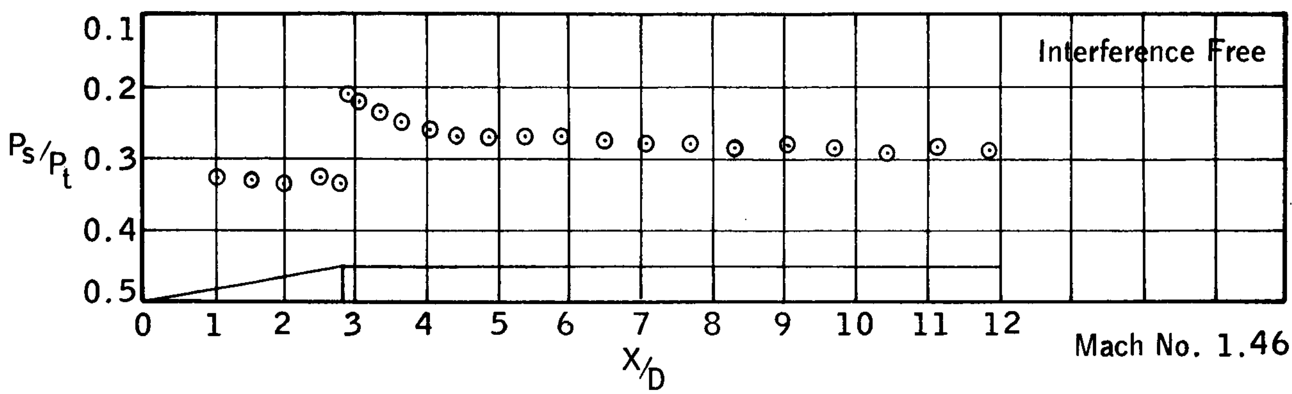



Mach No. 1.25

## Transonic Cone-Cylinder Pressure Distribution

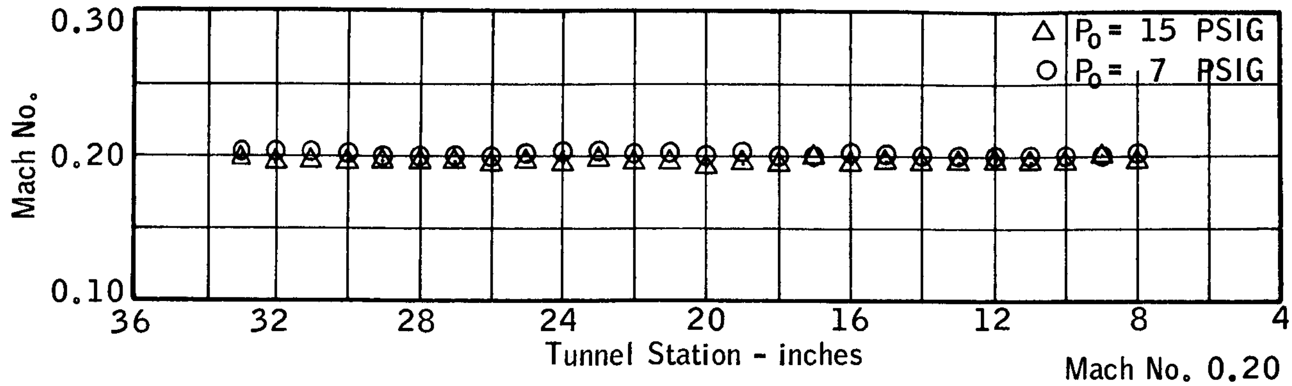


# APPENDIX B

## Mach Number Distributions

Mach Number Distribution for Transonic Test Section

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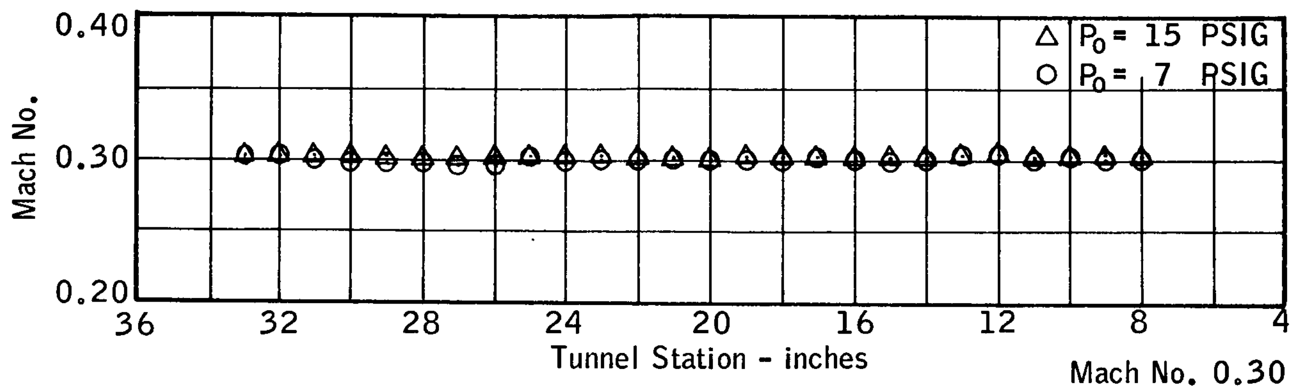


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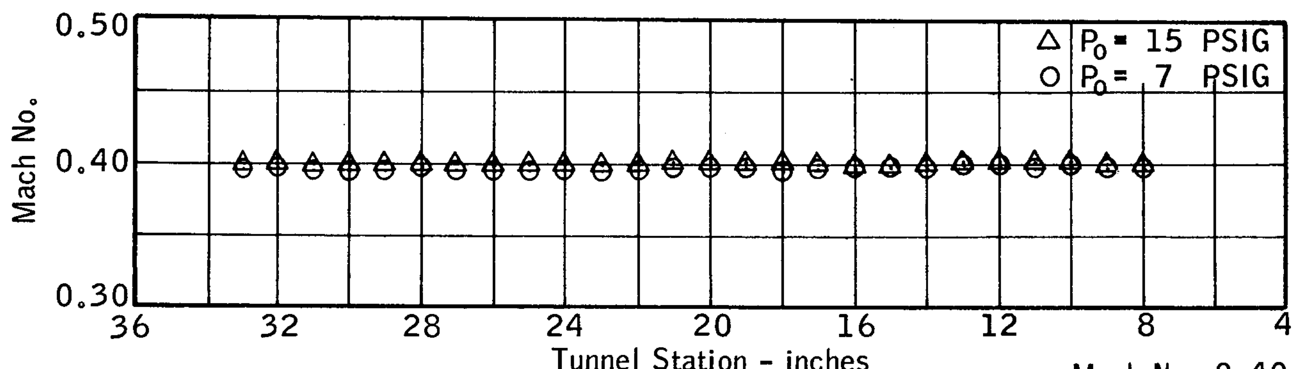


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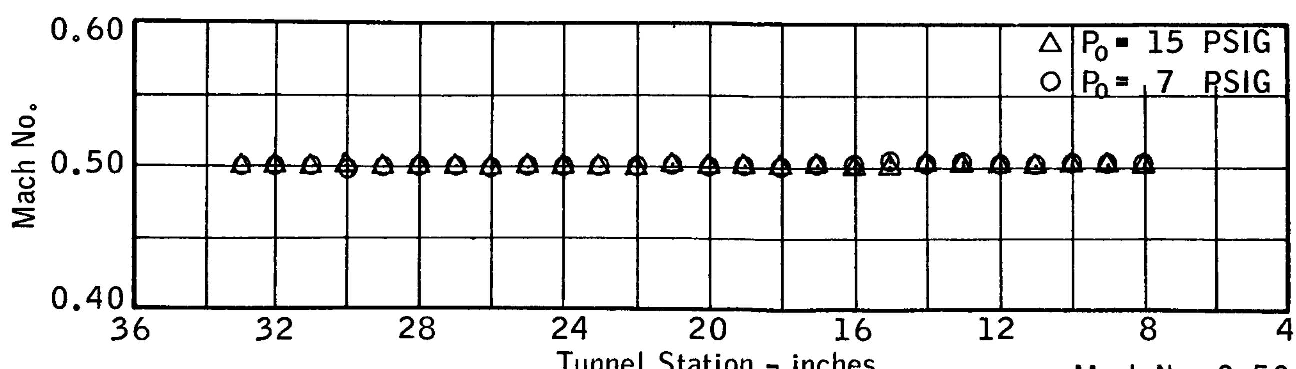


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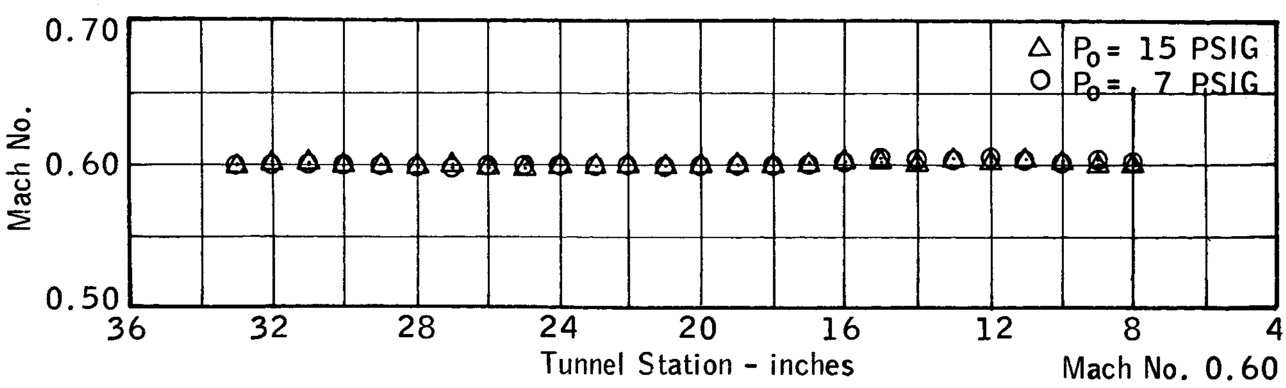
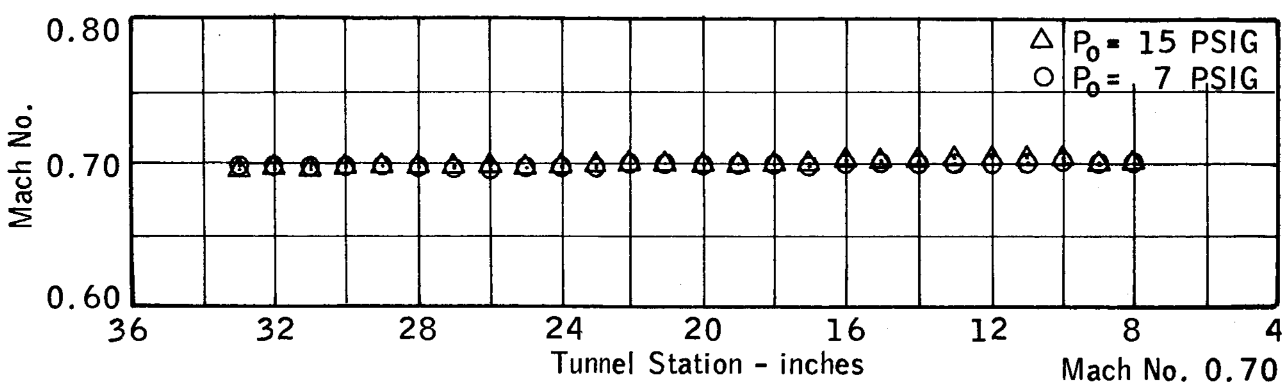
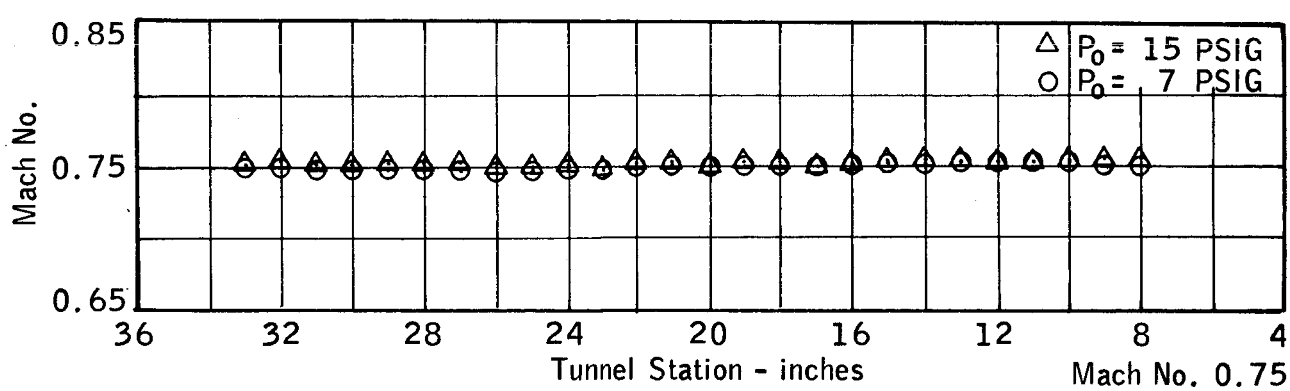
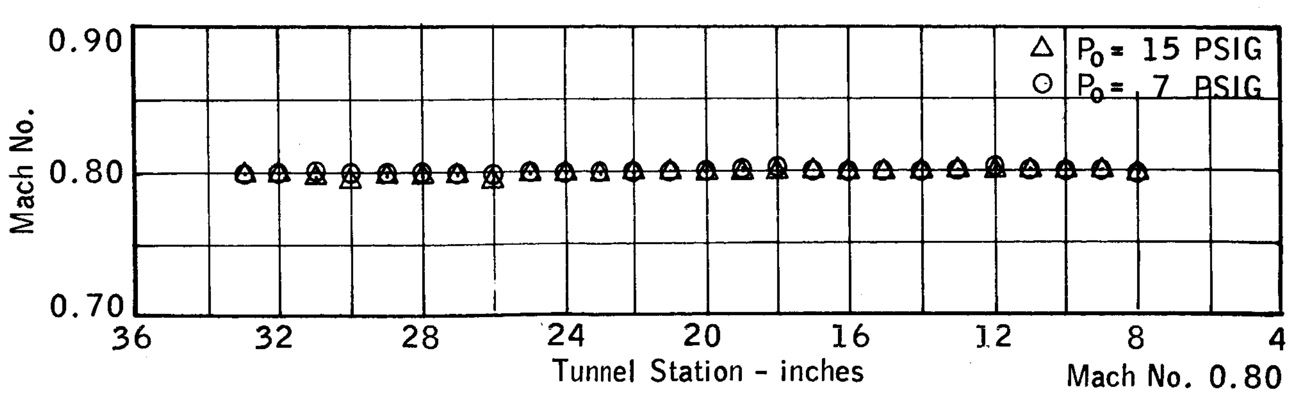
Mach Number Distribution for Transonic Test Section

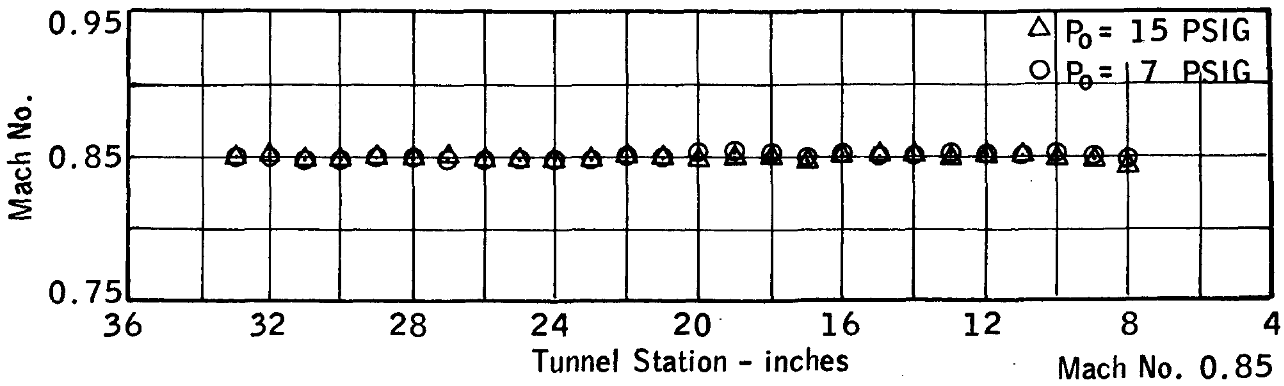


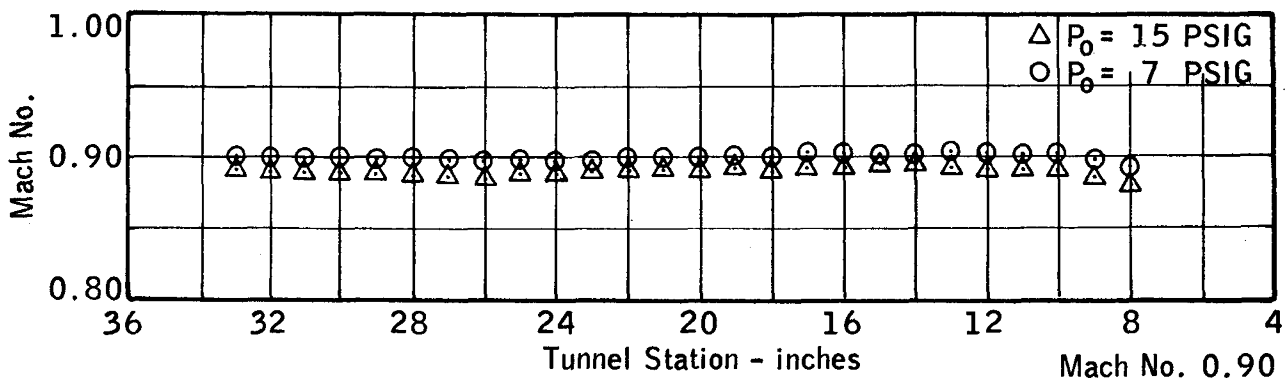



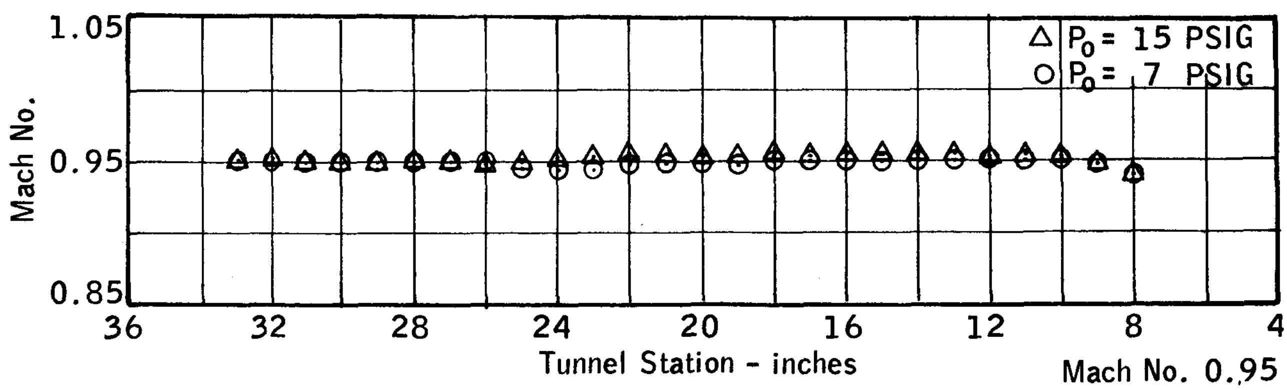



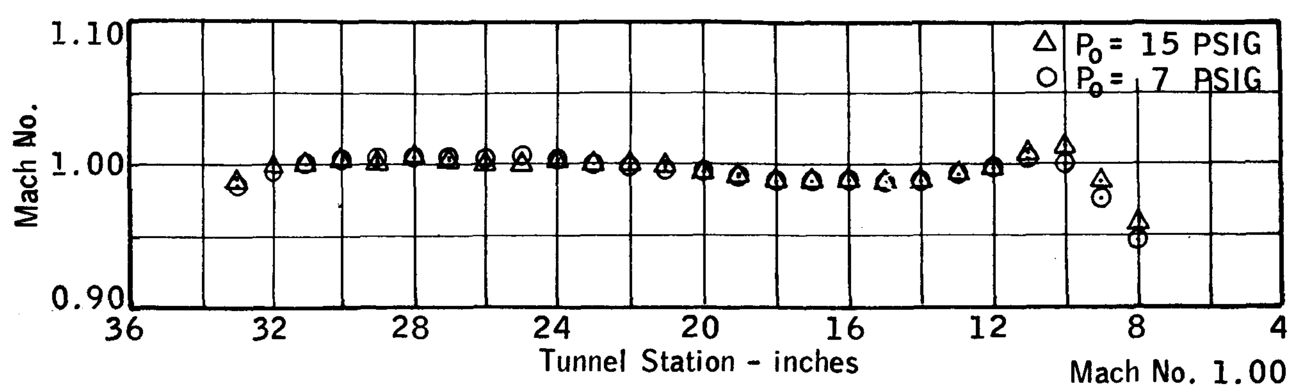



Mach Number Distribution for Transonic Test Section

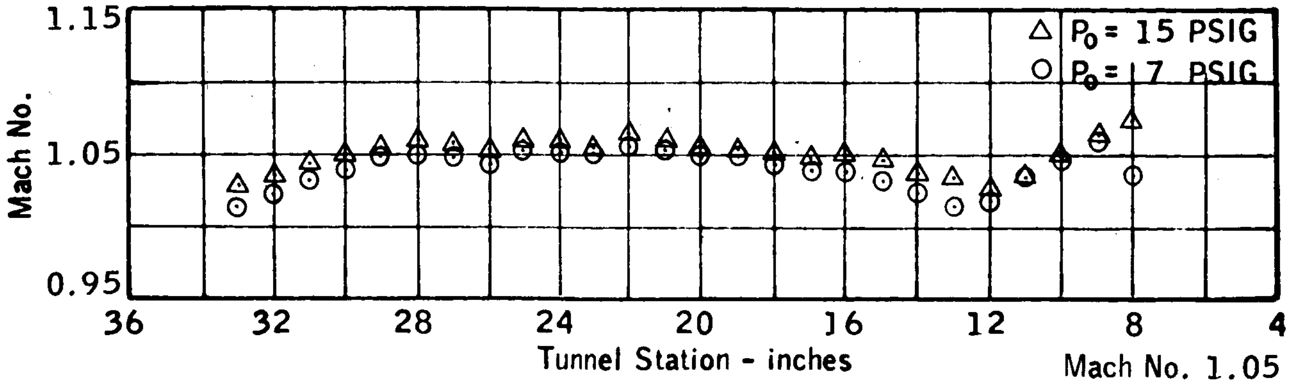


Mach Number Distribution for Transonic Test Section

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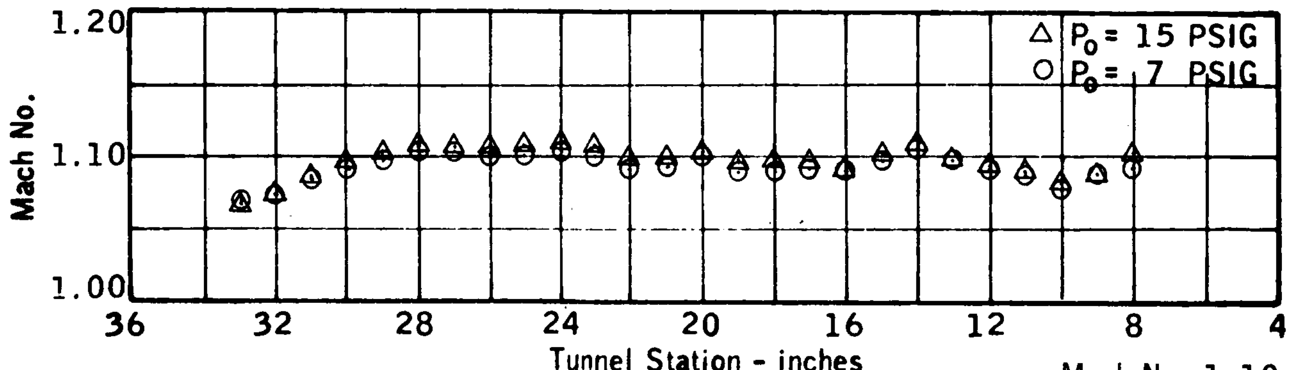


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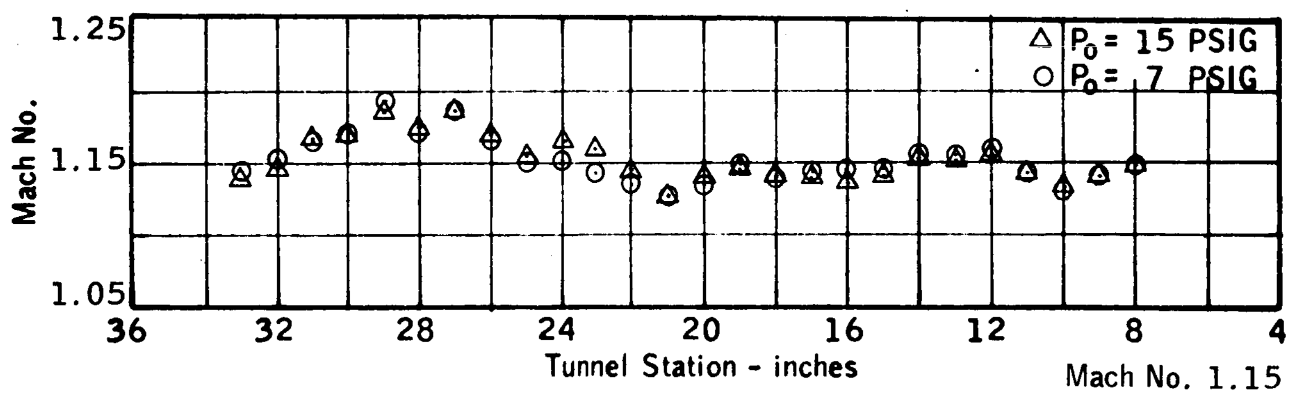


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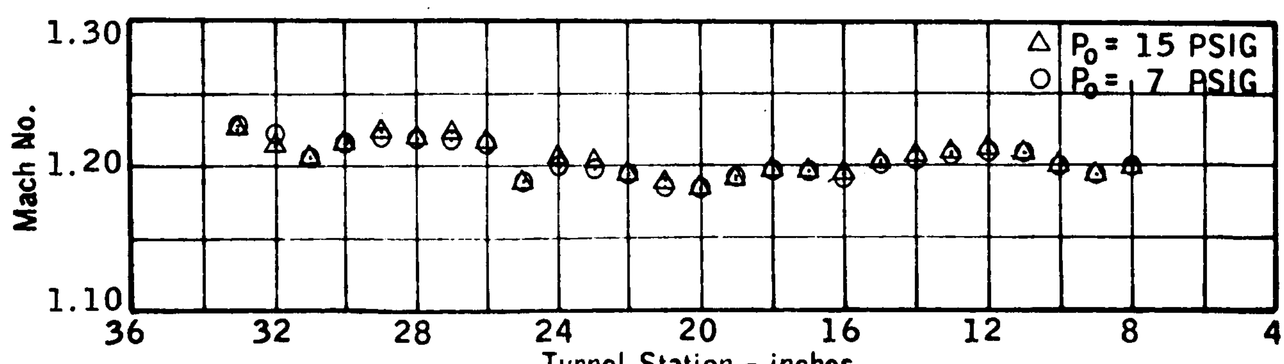


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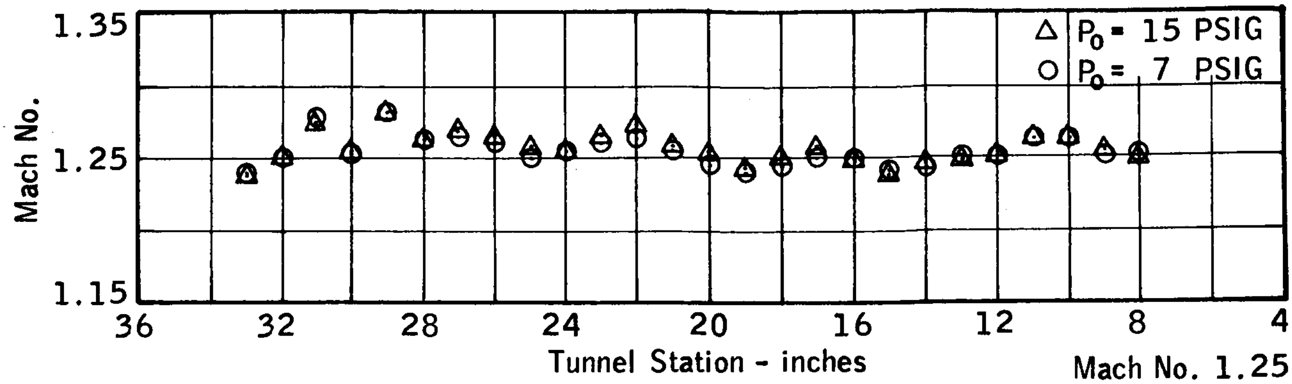
Mach Number Distribution for Transonic Test Section

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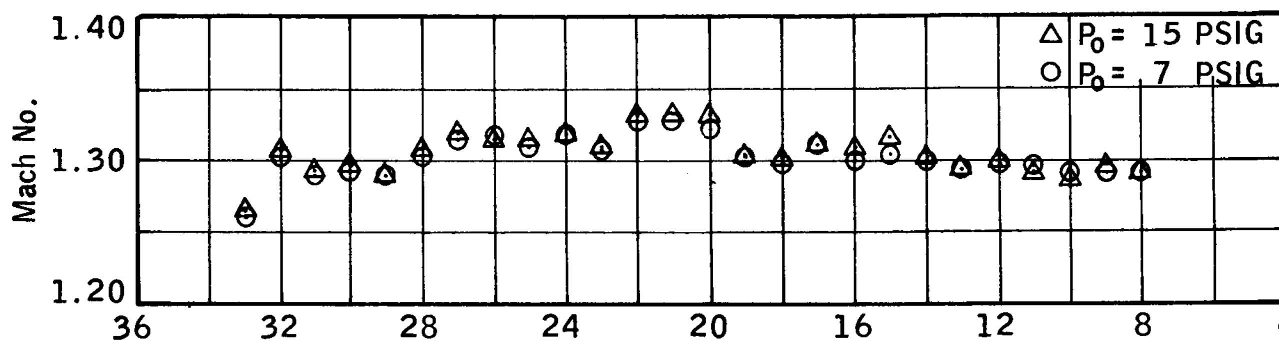


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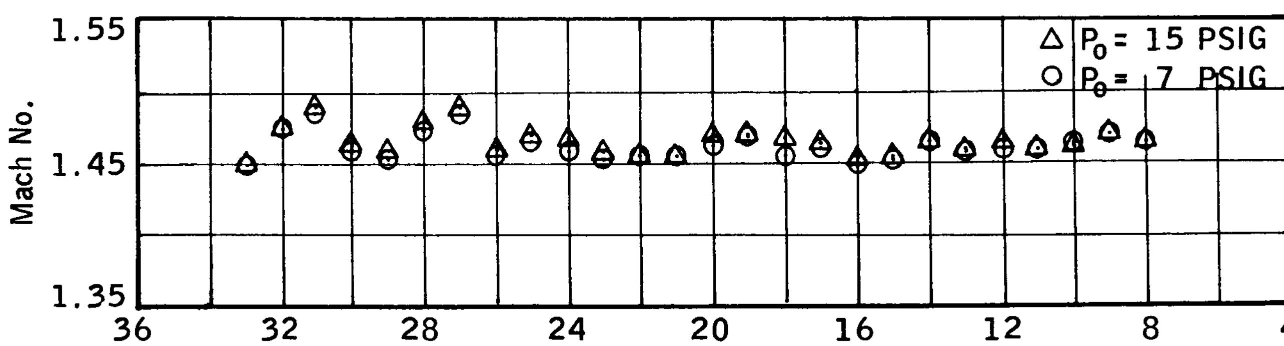


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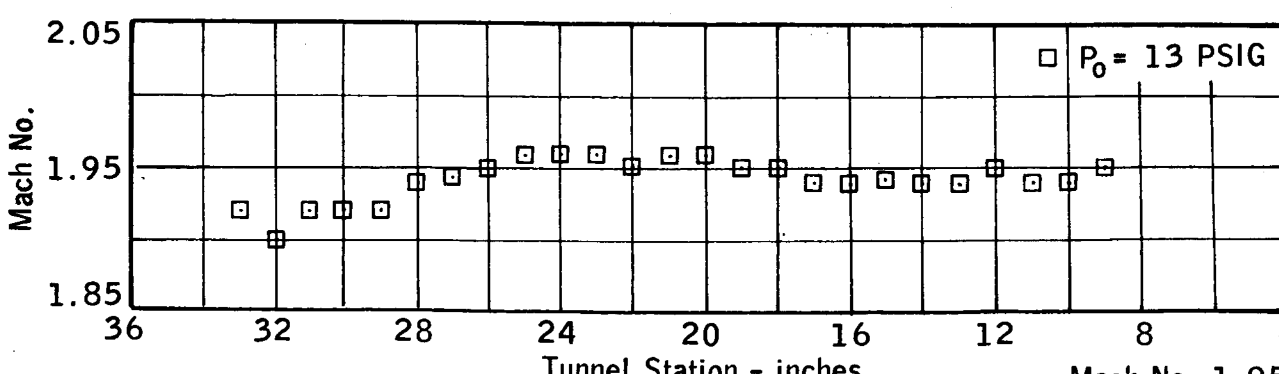


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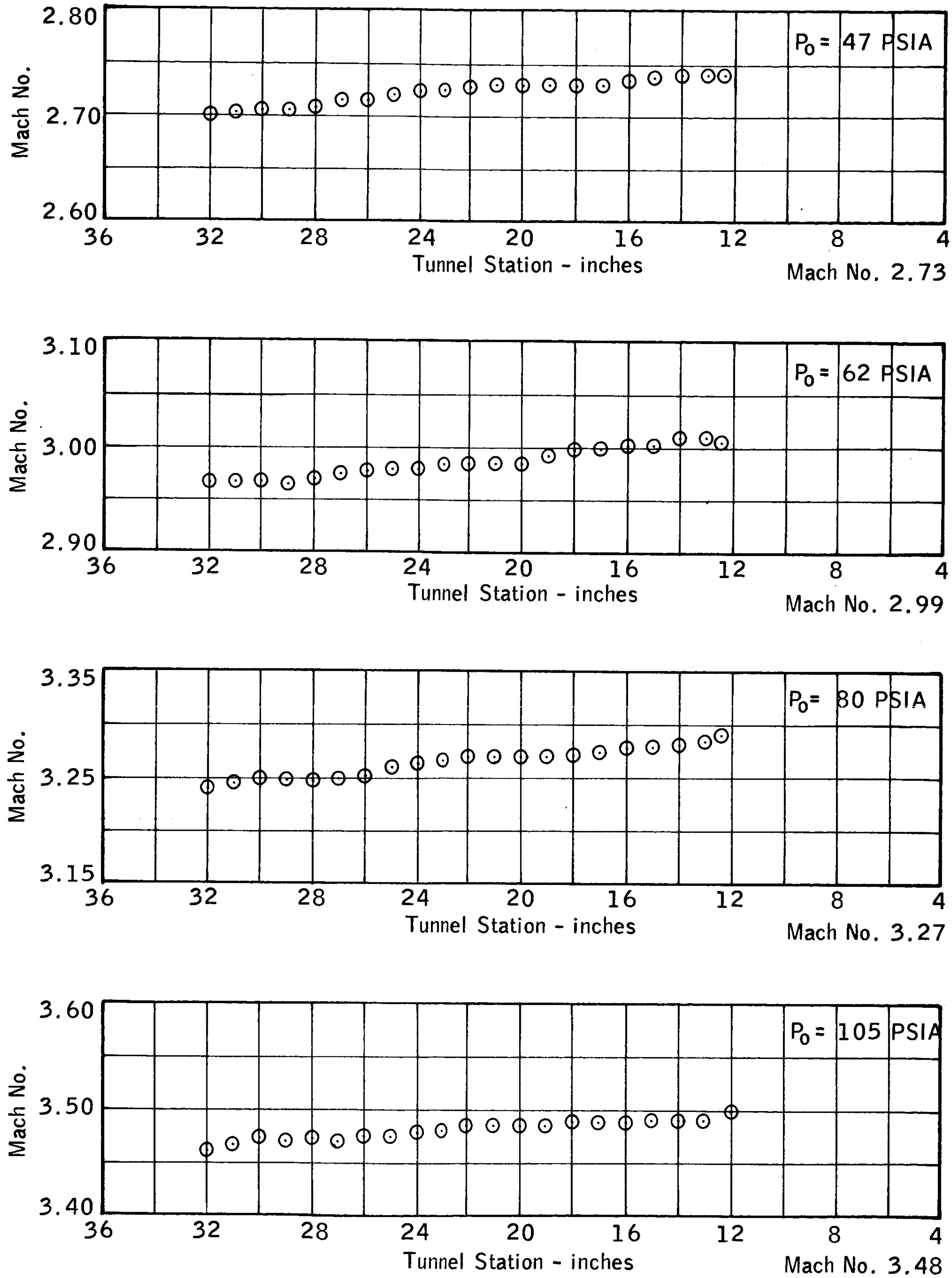
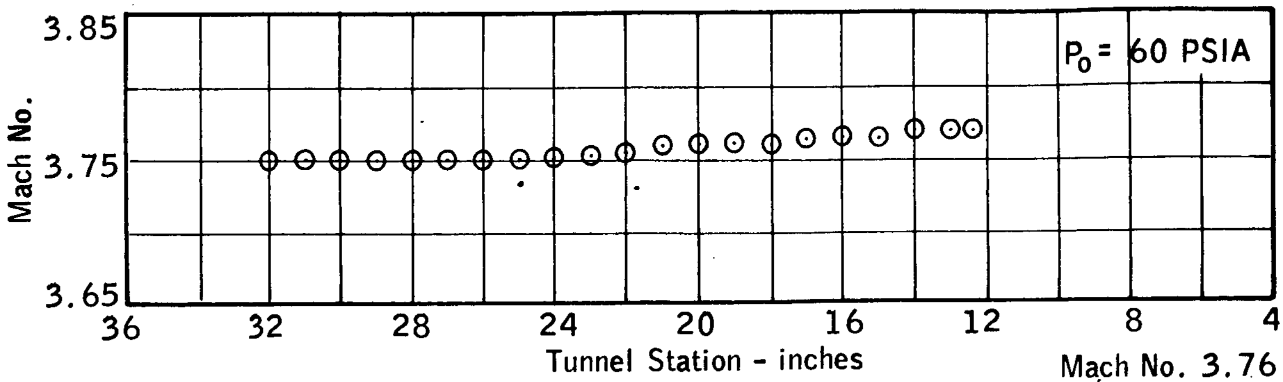
Mach Number Distribution for Supersonic Test Section



## Mach Number Distribution for Supersonic Test Section

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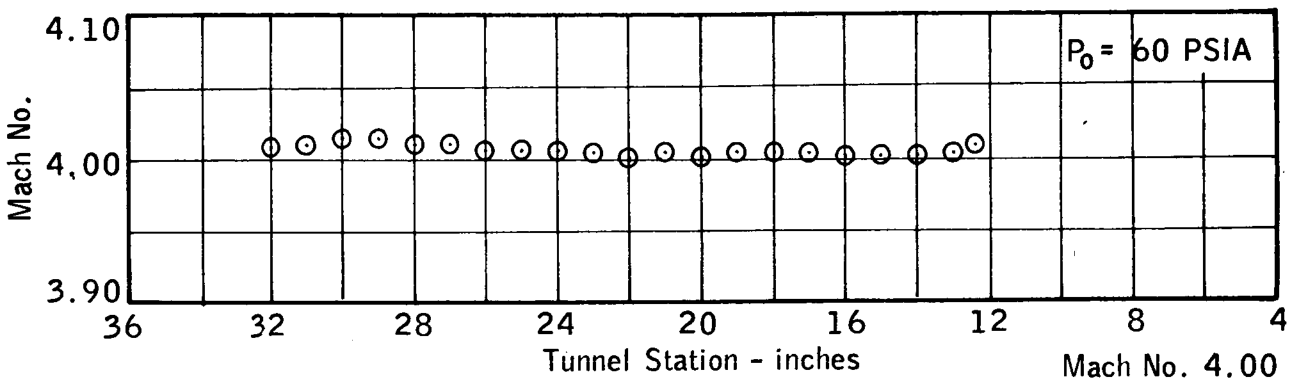


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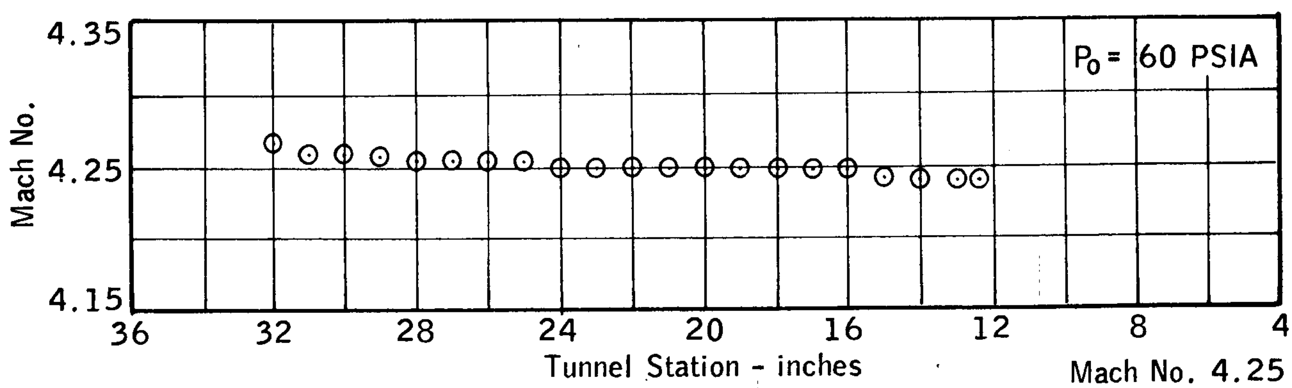


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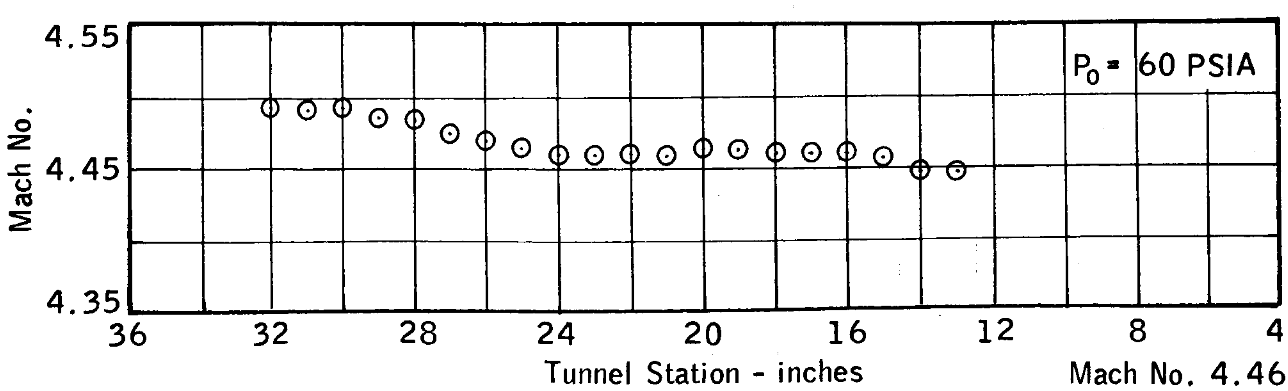
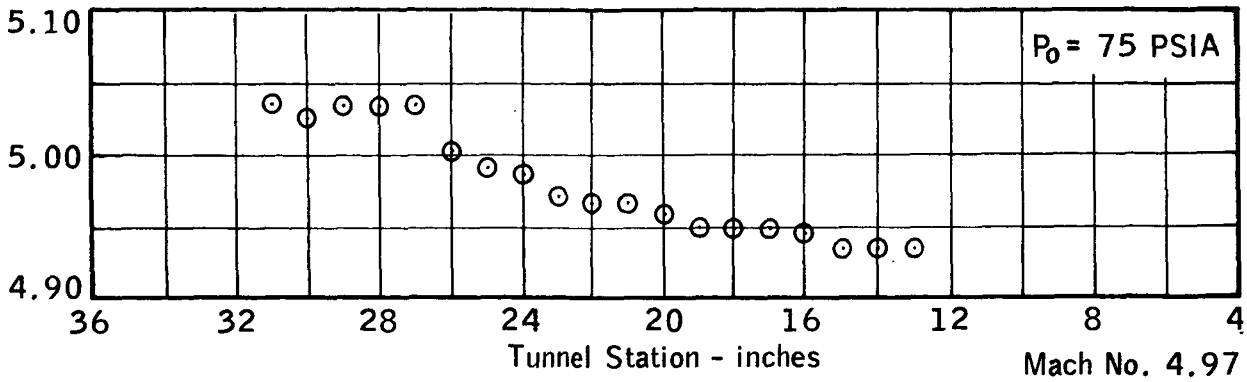



Mach No. 4.46

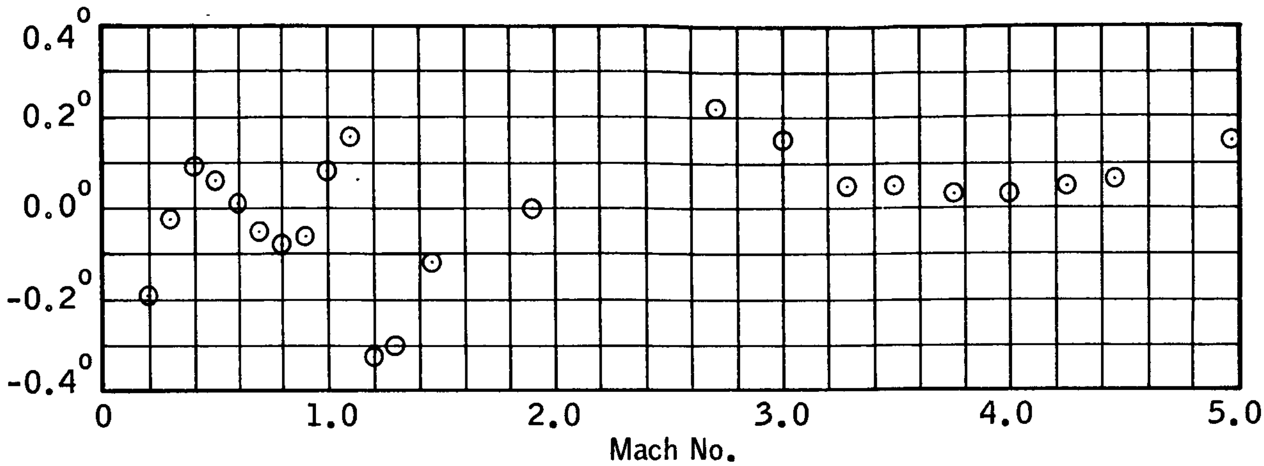
Mach Number Distribution for Supersonic Test Section



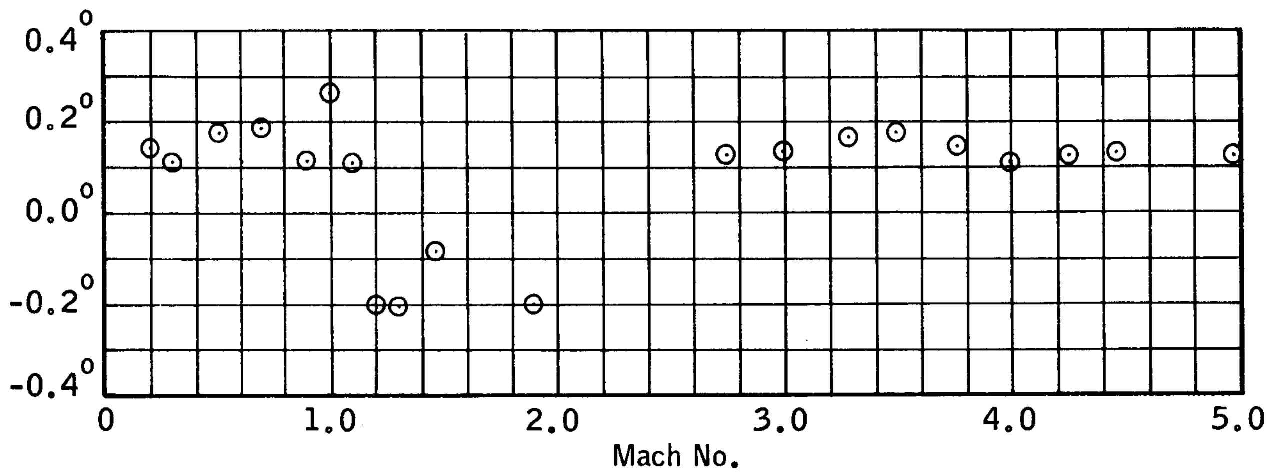
## APPENDIX C

## Flow Angularity

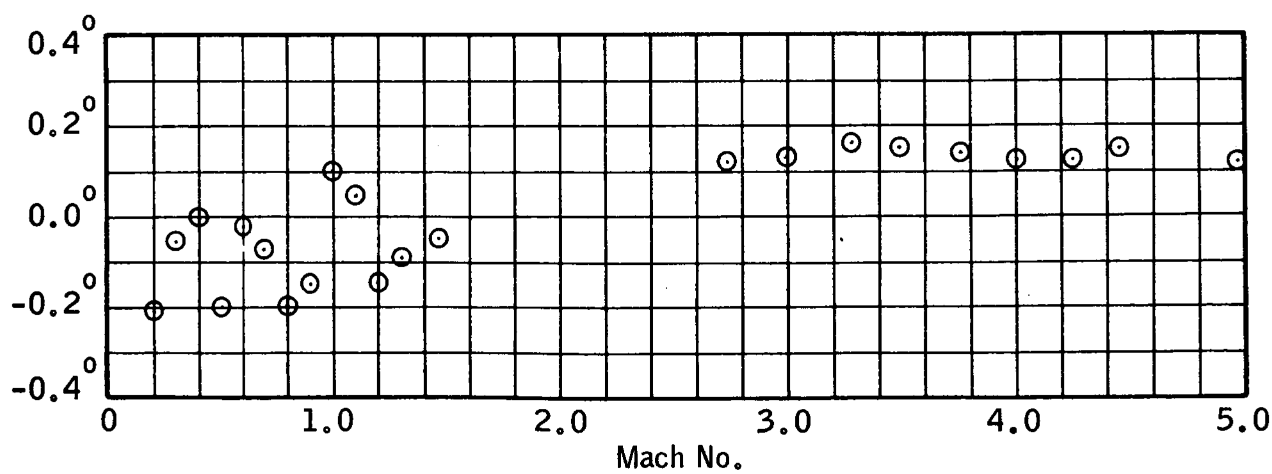
## FLOW ANGULARITY




Tunnel Station 13




Tunnel Station 21




Tunnel Station 27

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CALIBRATION TESTS OF THE MSFC 14 x 14-INCH TRISONIC WIND TUNNEL

By Erwin Simon

The information in this report has been reviewed for security classification. Review of any information concerning Department of Defense or Atomic Energy Commission programs has been made by the MSFC Security Classification Officer. This report, in its entirety, has been determined to be unclassified.

This document has also been reviewed and approved for technical accuracy.

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